METAL AND Pb ISOTOPE ANALYSES ON WEAPONS FROM THE BRONZE AGES IN SIDON:

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GAEL LE ROUX
ALAIN VÉRON
CHRISTIAN SCHOLZ

Introduction

Metal weapons found in Middle Bronze Age graves and fragments from a crucible found in an Early Bronze Age building were investigated at the Sidon College site (British Museum excavation). Our aim was to analyse metal and lead isotope chemistry at the Institute of Environmental Geochemistry, Heidelberg and at GEOTOP, Montréal, respectively. In this article, we describe the metal composition of newly analysed objects and we compare them with previous results on weapons from the EBA and MBA (Le Roux *et al.* 2004). Chemical analyses provide important information on the composition of the object, which is related to the technological processes. Additionally two artefacts are discussed for Pb isotope composition in order to trace the geographic source of metal.

Methods

Due to the uniqueness of the metal weapons, only corroded layers around the artefacts were sampled. Those are a mixing of altered metal but also soils from the excavation site. Corrosion induces many problems in the analyses of metal artefacts, but in a first approach, it enables the saving of samples and to characterize the average composition of the objects. Metal compositions were measured on an ICP-OES (Varian Vista-MPX) after hot digestion of total samples (20 to 100mg) using concentrated HNO_3 acid. Because in the measured samples, not only metals but also soil were digested, table 1 presents results of metals concentrations in % of measured total metal content. Aluminium and Iron concentrations are especially influenced by soil composition and corrosion as demonstrated by the 2 replicates of sample S/1820 (Le Roux *et al.* 2004) and thus also reflect the part of soil incorporated in the sample. Two subsamples of 4210/1954 were also analysed and give different results for Pb. This could indicate also an influence of soil for this element. However we think that this difference is more linked to metal corrosion and/or alloy heterogeneity.

Table 1: Metals concentrations of corroded samples in % of total metal content. Bi and Sb were also measured but were always under the detection limit of the method. u.l means under the limit of detection.

SAMPLE NAME	DATE	Type	Burial	Cu (%)	Ag (%)	As (%)	Au (%)	Fe (%)	Ni (%)	Pb (%)	Sn (%)	Zn (%)	Al (%)
1747/177/SQ. 9	Sidon´s level 1 (1st part of 19th century BC.)	Spearhead	5	97,16	ul	0,04	ul	1,30	0,01	0,10	0,50	0,03	0,88
1744/177/SQ. 9	" "	Axehead	5	97,24	ul	0,03	ul	0,23	0,00	2,28	0,11	0,01	0,11
1820/238/SQ. 6	" "	Axehead	12	83,59	ul	0,02	ul	10,88	0,01	0,73	0,56	0,03	4,18
Rep. 1820/238/SQ. 6	" "	Axehead	12	93,66	ul	0,02	ul	2,76	0,01	0,66	1,39	0,02	1,49
1821/238/SQ. 6	" "	Spearhead	12	98,31	ul	0,03	ul	0,35	0,00	0,03	1,16	0,00	0,11
3003/553/SQ. 25	" "	Axehead	23	72,52	ul	0,14	ul	0,52	0,00	26,23	0,42	0,02	0,16
1825/266/SQ. 11	" "	Spearhead	13	94,49	0,17	0,11	ul	0,86	0,00	0,20	3,78	0,04	0,35
1855/302/ SQ. 14	Sidon´s level 4 (Intermediate Early/Late Middle Bronze Age)	Arrowhead	14	96,34	0,10	0,28	Trace	0,71	0,01	0,26	2,12	0,03	0,15
1734/178/SQ. 6	Sidon´s level 5 (Late Middle Bronze Age)	Knife	4	97,15	ul	0,20	ul	2,11	0,02	0,12	0,12	0,02	0,25
Le Roux *et al.* 2004													
4140/1924/SQ. 36	Multiple burials MB IIB	Blade	75	98,78	ul	ul	ul	nd	0,25	0,01	0,09	ul	0,64
4063/2216/SQ. 37	Early Bronze Age	Crucible fragment		80,50	ul	0,19	ul	nd	8,38	0,07	0,01	0,14	0,02
4117/1940/SQ. 36	Warrior burial MB IIA	Arrowhead	78	97,68	ul	0,27	ul	nd	0,93	ul	0,02	ul	0,36
4149/1940/SQ. 36	Warrior burial MB IIA	Axehead	78	89,84	ul	ul	ul	nd	0,15	ul	8,71	ul	1,19
2916/1916/SQ. 36	Multiple burials MB IIB	Arrowhead	69	95,95	ul	0,19	ul	nd	1,90	0,01	0,25	ul	1,54
4056/1924/SQ. 36	Multiple burials MB IIB	Dagger	74	97,97	ul	0,45	ul	nd	0,26	0,01	0,07	ul	1,10
4210/1954/SQ. 36	Level 3 MB IIA	Knife	70b	98,25	ul	0,27	ul	nd	0,24	0,03	1,11	ul	ul
4210/1954/SQ. 36	Level 3 MB IIA	Knife	70b	95,48	ul	0,05	ul	nd	0,12	0,01	4,26	ul	0,00
2989/1917/SQ. 36	Level 3 MB IIA	Spearhead	70	97,60	ul	0,22	ul	nd	0,51	ul	0,75	ul	0,78
3562/2079-2071/SQ. 29	Multiple burials MB IIB level 6	Belt	42	88,76	ul	0,06	ul	0,00	0,16	0,01	0,72	ul	10,27
2715/1906/SQ. 36	MB II A/B	Knife	67	91,86	0,01	0,42	0,00	0,01	0,34	0,01	0,54	ul	6,70
2605/1846/SQ. 36	Level 6	Dagger	66	94,63	ul	0,06	ul	0,00	0,14	0,01	0,23	ul	4,93

Results and Discussion

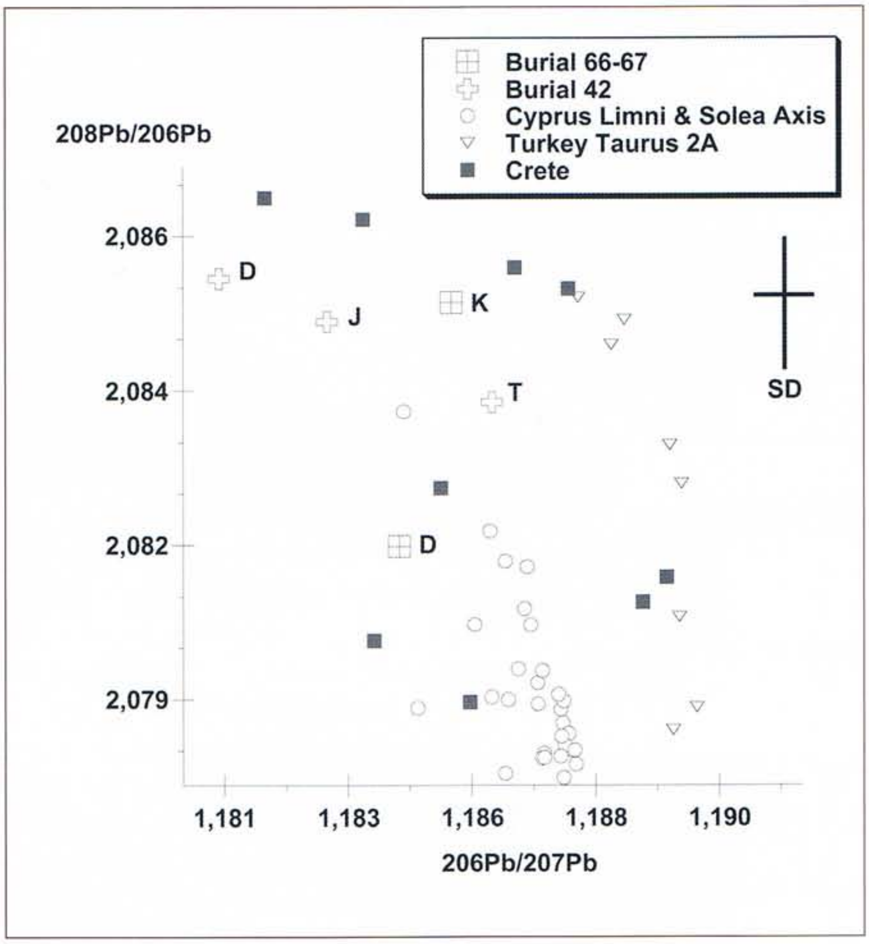
A large part of the samples measured during spring 2008 are made of low tin copper alloys. An Early Bronze Age sample (4063/2216 SQ37) is enriched in iron and aluminium, which is possible in copper alloy. However this can also be due to soil contamination. Two samples (4149/1940 SQ36, 4210/1954 bronze sompk SQ36) are clearly lead-copper alloys, whereas the other are just copper objets. 4210/1954 was found in burial 70 with 2 objects made of copper.

Three samples are different (3562/20-79 burial 47; 2715/1906 burial 67, 2605/1846 burial 66) and made of bronze (Cu+Sn) with a different percentage of tin in the alloy and no measurable aluminium. The metallurgical technique is therefore clearly different than the previous discussed objects. Two of these objects (2715/1906 burial 67, 2605/1846 burial) were analysed for Pb stable isotopes in order to restrict the geographical origin of the body ores used to fabricate these artefacts. Indeed, as described in Véron *et al.* (in this issue p. 68), Pb is commonly found in copper (Cu), tin (Sn) and silver (Ag) deposits that can be identified by their relative proportion of Pb isotopes (^{204}Pb, ^{206}Pb, ^{207}Pb, ^{208}Pb) (see ref in Véron *et al*, *AHL*, this issue). Bronze artefacts recovered from burial 66 and 67 are a dagger and a knife from the Middle Bronze Age (Table 1). These objects have been prepared for analysis by MultiCollector-Inductively Coupled Plasma Mass Spectrometry (MC-ICPMS) at GEOTOP (ISOPROBE, UQAM, Montréal) as decribed in Véron *et al.* (in this issue p. 68). The $^{208}Pb/^{206}Pb$ vs. $^{206}Pb/^{207}Pb$ ratios of burial 66-67 artefacts are presented in figure 1, and compared to Pb isotope imprints from Eastern Mediterranean ore deposits that fall within the range of these artefacts (Greek, Turkish and Cypriote signatures). Also shown are the bronze artefacts from burial 42 that are discussed in Véron *et al.* (in this issue p. 68). The edge of the Turkish Taurus isotope field might slightly overlap the burial 67 knife imprint. This artefact also ranges close to the isotopic field of burial 42 artefacts, centered within the Cretan ore field, and therefore is more likely to originate from Crete (fig. 1). For the burial 66 dagger, a Cypriote source could be invoked from Limni and Solea Axis (Stos-Gale *et al.*, 1997) along with the Cretan source (Gale and Stos-Gale, 1986). Cu ores from Limni and Solea are mostly cupriferous pyretic deposits that are enriched in iron (Fe) (Stos-Gale *et al.*, 1997). Meanwhile, Fe content of the burial 66 dagger is lower than 0. 3% (Table 1) suggesting that the Cretan ores are more likely to explain the origin for this bronze artefact. Furthermore the burial 67 knife (from Crete) and burial 66 dagger display similar metal concentrations, reinforcing a possible identical origin for both artefacts from Crete.

Here the combination of elemental abundances and isotope imprints contributes to reasonably conclude on a Cretan provenance for both bronze artefacts. These results strengthen findings by Véron *et al.*, (in this issue p. 68) on the development of trading activities between Sidon and the Minoan civilization during the Middle Bronze Age.

Conclusion

Compared to previous results (Le Roux *et al.* 2004), many objects are again poor or do not contain any tin. Generally, based only on the metal composition of each object and excluding the three samples discussed above, it is difficult to distinguish any group of objects characterized by a common metallurgical technique.
Three objects are made of real bronze alloy (Cu+Sn). Pb isotopes on two of these objects allow fingerprinting of metal origin and confirm a common metallurgical and ore origin from Crete.



1 Comparison of isotopic imprint ($^{208}Pb/^{206}Pb$ vs. $^{206}Pb/^{207}Pb$ ratios) of (B66-B67) burial bronze artefacts to those of burial 42 and Eastern Mediterranean ore deposits (see references in Véron *et al.*, AHL, this issue, Figure 3). SD denotes the maximum Standard Deviation from reported published data. Specific annotations identify burial artefacts: K (Knife), D (Dagger), T (Torque), J (Javelin head), B (Belt dics).

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